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ARTICLES

HOW THE BRACKEN PLANT REACTS TO TREATMENT

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In their recent report the Scottish Hill Farm Research Committee [1] comment on the lack of any complete interpretation of the behaviour of the common bracken fern (*Pteridium aquilinum* (L.) Kuhn) and point out that, though some rather uncertain degree of control can now be achieved, such control seldom leads to eradication, and that treatment of bracken lands must still be followed by constant vigilance to maintain suppression. In the hope that greater understanding of the plant's behaviour may explain the difficulties of eradication and may point the way to other lines of attack, the present article describes some analyses lately carried out in the west of Scotland on the underground stem of the bracken plant and on its reaction to certain forms of treatment. A report by one of us on some aspects of this work has already been published elsewhere[2].

Present-day methods of treating areas invaded by bracken fall, in the main, into two categories: (*a*) mechanical, in which the land is ploughed or the fronds are destroyed by cutting, crushing or bruising; and (*b*) chemical, in which the plants are sprayed with toxic agents, such as sodium chlorate or organic compounds of the selective weed-killer type.

It is generally accepted that ploughing is the most effective method, and areas which can be so treated present little difficulty to the agriculturist. Much of the underground stem thrown up by the plough dries up and is killed completely; and though some small fragments may re-establish themselves and set up new centres of growth, they are easily recognized and removed before they become firmly established. The necessity must be stressed, of course, for putting such land immediately into continuous cultivation, before re-infection by bracken takes place. Problems of land usage thus go hand in hand with bracken clearance.

It is, however, the very large tracts of unploughable land in Scotland and elsewhere that cause concern. In such places attack has so far been concentrated on the fronds—the only organs of the plant to come above the ground—although it is known that, in their attack on the fronds, none of the mechanical or chemical methods are entirely efficacious (Home [3], Smith [4], Braid [5], and Holly *et al.* [6]). Up to the present only Smith has sought to explain his findings by referring

to the reaction of the underground stem. The present experimental work had as its object the examination in greater detail of the behaviour of the underground stem under different treatments, and particularly the mode of re-establishment of growth when controlling treatments ceased.

The underlying principles of assault on the fronds are based on recognition of the frond as the organ which provides nutriment for the growing regions and builds up food reserves by means of its photosynthetic activities. Removal of such nutritive organs must lead to the using up of reserves from the thick underground stem, and without replacement of those reserves the plant must ultimately starve to death.

The success of methods of treatment has so far mainly been measured by evaluation of the number of fronds on a unit area, and of height or weight as a measure of frond size. Many observations (Smith [4] and Braid [7]) have shown a reduction in frond size after treatment by cutting, but the numbers of fronds in a given area have not always shown a comparable fall. It has long been known (Smith [4]) that cutting for a few years does not eradicate the plant entirely, and that if left uncut it will return. Recently, the importance was stressed (Conway [8]) of recognizing that, in Great Britain at any rate, the plant is rarely spread by the development of new young plants from spores, but that the deep-seated underground stem is the main agent of spread. It is the underground stem, therefore, which should be the object of attack.

Structure of the Bracken Plant

The underground stem grows more or less horizontally (though it sometimes runs down to a depth of about two feet) and is therefore well protected against damage and adverse weather. It branches frequently, and may be as much as $1\frac{1}{2}$ inches in diameter. True roots are borne along its whole length, and fronds occur on alternate sides. On the very vigorous, deeper rhizomes, fronds are produced only at considerable intervals, but on the smaller stem branches, near to the soil surface, the fronds are crowded together. On any branch of the undisturbed mature rhizome there is normally only one frond per year, and the dense stands of fronds seen above ground give some idea of the close network of branches present below the surface of the soil.

Figure 1 is a diagrammatic representation of a typical stem apex. The expanded frond of the current season is seen to lie some distance behind the growing tip ; and between it and the apex of the stem is a young frond bud,* which will normally expand in the following

*Throughout this article, the term " frond bud " refers to the young frond when it is still completely below ground and before the branches are developed ; " frond " or " expanded frond " refers to the fully developed frond with unfurled branches.

season. In front of the young frond bud, and nearer to the stem tip, is a lateral bud, which will probably develop into an expanded frond in two years' time. Altogether, it appears that, in a region such as the west of Scotland, field bracken normally takes four years to develop

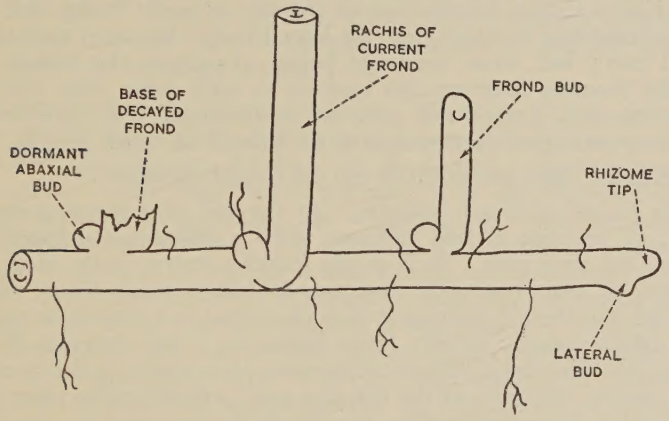

Fig. 1. Diagram of the apex of a rhizome branch, showing stages in the development behind the apex of fronds and abaxial buds.

an expanded frond from the frond rudiment arising at the apex of the stem to the fully expanded structure showing above ground. This agrees with the earlier description of Klein [9]. After the frond dies, remnants of it remain on the older parts of the stem for several years.

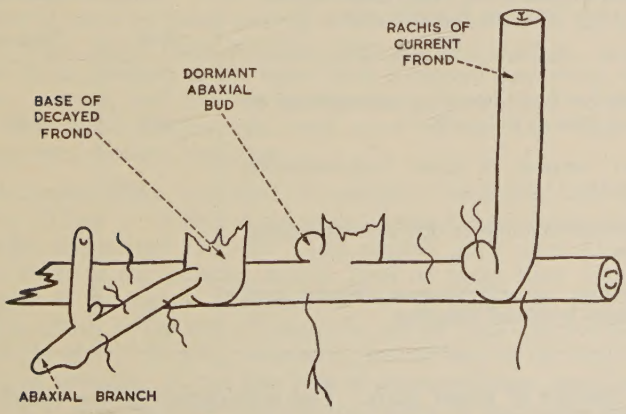

Fig. 2. Diagram of a rhizome branch at an older phase than Fig. 1, showing the development of a secondary branch from one of the basal abaxial buds.

Occasionally the tip of the stem bifurcates, but most frequently branching results from the development of branch buds laid down at the bases of the fronds on the sides away from the stem apex (Fig. 1 : abaxial bud). The great majority of fronds have a single bud in the abaxial position ; a few are without buds ; and, very rarely, a frond may have a second branch bud on the side opposite to the first one. The abaxial bud develops from the lateral bud at the same time as the frond bud ; but, when the frond begins to expand, the branch bud usually becomes dormant and remains so until some time after the frond has died. Later it may grow out into a branch (Fig. 2), following the same pattern of development as the branch on which it arose.

There are three points which call for special comment :

The Extent of Frond Initiation. At the end of a growing season, about 50 per cent of field rhizomes show a differentiated frond bud behind the stem apex. Early in the growing season (early May), the number of stem tips with these frond buds is much lower, which suggests that their development from the lateral bud stage is associated with photosynthetic activity (June-September), and supports Watt's finding [10] that frond differentiation takes place chiefly in the summer. The greatest extension of the rhizome apex probably takes place later (September-November), after the fronds have ceased to function. This suggestion is supported by the numerous, markedly active stem tips observed by us during late autumn in the west of Scotland, a region where the mild autumn weather may prevent any marked fall in soil temperature until late in the winter.

Table 1

Seasonal Rhizome Development in the West of Scotland

Mean Figures from Three Experimental Areas (Sites A, B and F., see p. 7)	Analyses made in	
	May	*September*
Number of fronds showing above ground on field plots of 100 sq. ft.	215	280
Ratio: number of frond buds/expanded fronds	1.93	1.96
Percentage of rhizome tips bearing a frond bud	27	57
Percentage of current-year fronds with abaxial buds and branches	36	72

The Number of Frond Buds. The relationship of the numbers of fronds and frond buds on bracken rhizomes in Breckland has been commented on by Watt [10]. Analyses made in the west of Scotland have again almost invariably shown a higher number of frond buds

than of current-year fronds, so that an excess of frond buds is probably one of the features in the development of the plant. It seems unlikely that there is any dormant period in the growth of the frond, rather it appears to be slow and continuous ; but when a frond is killed or badly damaged, it is replaced by the frond bud next to it, which then develops faster than usual. Analyses made in the spring and autumn show that the number of frond buds throughout the season is normally about twice that of the expanded fronds (Table 1).

The Development of Secondary Branches. The dormant branch buds at the abaxial bases of the fronds form a considerable reserve from which new branches can develop. At the end of a growing season, large numbers (often more than 80 per cent) of the current-year fronds carry such buds ; in the spring, and while the frond buds are young, branch buds are not visible to such an extent. Hence their first external appearance seems to be correlated with the age and maturation of the adjacent frond bud. So long as the frond is functional, the bud remains dormant ; but if the plant is disturbed in any way, or if the adjacent frond dies, the dormancy of the bud may be broken and the secondary branch may begin development. While the main branches of a rhizome are believed to effect the major spread of the plant, it is probably the growth of these smaller secondary shoots which brings about the consolidation of the stem and the denseness of frond growth. The extent to which these secondary shoots are initiated and develop is therefore of considerable ecological interest.

Mechanical Treatment

A test of the morphological reaction of the underground stem to cutting treatments of differing severity was carried out in the west of Scotland from 1950 to 1953. The treatment given was complete defoliation of areas by hand-cutting, which, in its effect on the plant, may have been rather more complete than machine-cutting. It is no easy task for a machine to cut away from a treated area every frond above the ground, and for that reason the older method of frond-cutting with hand instruments, such as a scythe, may have had advantages over modern machines.

The treatment given consisted of complete defoliation from plots measuring 10 feet × 10 feet at intervals of about four weeks through the growing seasons of 1950-52. The marked plots were hand-cut (*a*) once, early in the growing season (end of May) (Cut I plots) ; or (*b*) twice, at the end of May and the end of June (Cut II plots) ; or (*c*) three times, at the end of May, the end of June and the end of July (Cut III plots). Nearby, untreated plots of land of the same area were used as controls. In the first year of the experiment, seven areas were treated. Of these, three were left untouched in the second season, so that the effect of only one year's treatment could be assessed ; the other four areas were treated for a second season, and three of them were again defoliated through a third season. Since it is the extent of

recovery after such treatment which is of interest to the agriculturist, in the fourth season (1953) one final cut was made in May from all the experimental sites treated for three years, after which they were left for the rest of the season. In September a last examination was made to test the degree of recovery shown by the rhizomes.

Table 2

Rhizome Development at the End of One Year's Cutting Treatment

Mean Figures from Seven Experimental Areas (Sites A-G, p. 7)	Control	Cut I	Cut II	Cut III
Number of fronds per 100 sq. ft. developed throughout the season	275	376	476	408
Number of fronds per 100 sq. ft. showing in September	275	216	54	13
Ratio: number of frond buds/ expanded fronds	1.46	1.39	1.64	1.02
Percentage of rhizome tips bearing a frond bud	55	61	83	100*
Percentage of living rhizome tips in an active condition	12	8	11	9

*The samples from this treatment showed that a high proportion of stem tips carried more than one frond bud: the ratio of frond buds to rhizome tips was 1.90 in these samples, compared with 0.55 from the control samples. This was the highest ratio recorded in the present series of experiments, though still higher ones have been found on young sporeling plants.

Table 3

Rhizome Development at the End of a Year of Recovery following One Year's Cutting Treatment

Mean Figures from Three Experimental Areas (Sites C, D and E, p. 7)	Control	Cut I	Cut II	Cut III
Number of fronds showing above ground per 100 sq. ft.	219	242	301	237
Ratio: number of frond buds/ expanded fronds	2.27	1.93	1.38	0.73
Percentage of rhizome tips bearing a frond bud	51	74	79	100
Percentage of living rhizome tips in an active condition	16	25	18	8

During the years of treatment, analyses were made on the rhizomes present in sample sods, measuring 2 feet 6 inches × 1 foot, taken from each of the experimental plots. A final analysis in September 1953 was made on 100 rhizome apices collected at random from each of the three-year treated areas. As far as possible, all analysis figures have been tested statistically; for convenience, the results are shown in the tables as mean figures.

The experimental sites used were in the following areas:

A. Drumclog Moor, Dumbartonshire: peat moor with acid soil (soil *p*H 5.6)*.

B. West of Scotland Experimental Station, Ballochraggan, Perthshire: hill pasture about 400 feet above sea level (soil *p*H 6.1).

C. Skemore Farm, Luss, Dumbartonshire: pasture land in hill glen (soil *p*H 5.8).

D. West of Scotland Experimental Station, Ballochraggan, Perthshire: stream-side area at the foot of the hill below Site B. (soil *p*H 5.8).

E. Rhu, Dumbartonshire: sheltered, deforested area (soil *p*H 5.5).

F. Killearn House Estate, Stirlingshire: deforested site now recolonizing with scrub (soil *p*H 5.6).

G. Balmaha, Stirlingshire: arable land at edge of oak wood (soil *p*H 5.8).

Analyses. The following points in the analyses of the rhizomes from the treated plots appear to us to be worthy of note.

1. No perceptible effects resulted from one year's cutting treatment. Even after severe cutting, the number of fronds expanding in the season after treatment was slightly, though not significantly, higher than on the controls (Table 3).

2. An observed, though not statistically significant, increase in the total number of fronds expanding on the plots treated during the first and the second years of treatment was noted (Tables 2 and 4)—an observation which was also made by Smith [4]. Both Smith and Watt [10] suggested that, after defoliation, the fronds showing above ground developed at the expense of the excess of frond buds, and our analyses confirm this suggestion. By the end of the second year of treatment, the ratio of frond buds to expanded fronds for Cut III was significantly less than the controls. (Table 4 and Fig. 3.)

3. With severe cutting for one year, the main effect on the rhizome was a tendency for an increase to occur in the number of rhizome tips carrying a frond bud, which was seen as a rise in the frond bud/rhizome apex ratio (Table 2). This rise continued in the following year, even though there was no further cutting (Table 3). Such increased frond bud formation would, of course, lead to more frond formation in the following year.

*All *p*H measurements were made by capillator, with bromo-cresol purple as the indicator.

4. At the end of two years of severe cutting, there was an apparent, though not significant, increase in the number of rhizome tips in an active state (Table 4).

5. After three years' cutting, statistically significant differences between the treated plots (Cuts II and III) and the controls were shown as follows (Table 5) : (*a*) the treated plots showed a greater proportion of dead rhizome tips ; (*b*) since the smaller proportion of living tips consequently carried relatively fewer frond-initials, the expansion of fronds was less ; (*c*) these expanded fronds were much smaller than those on the control plots.

6. Signs of recovery were, however, clearly seen on the rhizome at the end of the first season following the three years' cutting (Table 5 and Fig. 3). On the plots cut two and three times each year during treatment, there was a statistically significant increase (*a*) in the proportion of active rhizome tips among those still living, and (*b*) in the frond bud/frond ratio, which would, of course, lead to an increased number of fronds above ground in the following season. This suggests that, even after treatment as drastic as nine cuts in three years, the plant was still capable of vigorous recovery, and that the check given by the cutting treatment could be overcome in a relatively short time.

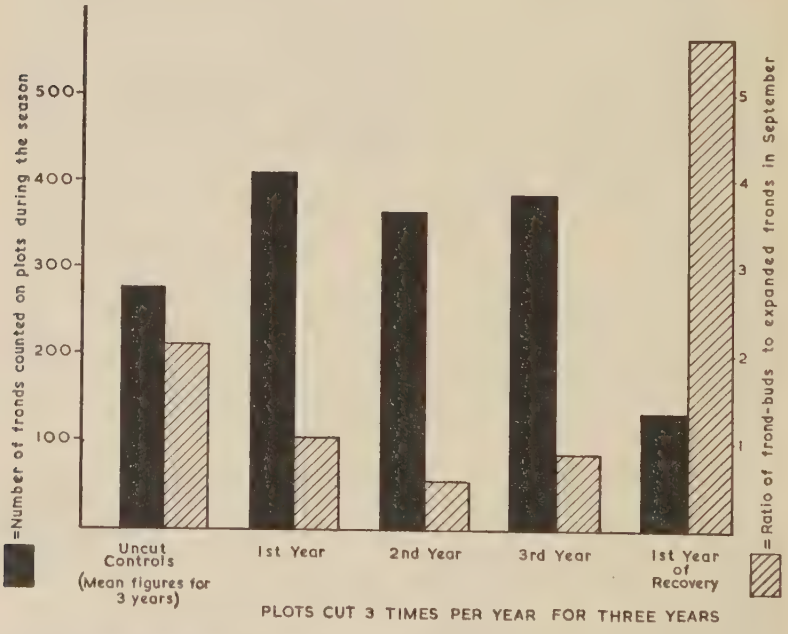

Fig. 3. The relationship, seen during the three years of a cutting experiment and the first year of recovery, of the expanded fronds showing on experimental plots and the hidden reserve of frond buds.

Fig. 3 illustrates two points of the bracken cutting experiments: (*a*) that a slight increase in the number of expanded fronds was seen in the early stages of the experiment; and (*b*) that though the number of expanded fronds decreased significantly after three years' intensive cutting, a significant reserve of frond buds was built up underground as soon as treatment stopped. Should there be no further treatment, these would soon re-establish the plant.

Table 4

Rhizome Development at the End of Two Years' Cutting Treatment

Mean Figures from Four Experimental Areas (Sites A, B, F and G, p. 7)	Control	Cut I	Cut II	Cut III
Number of fronds per 100 sq. ft. developed throughout the season	253	379	385	362
Number of fronds per 100 sq. ft. showing in September	253	183	51	11
Ratio: number of frond buds/ expanded fronds	2.29	2.21	1.14	0.55
Percentage of rhizome tips bearing a frond bud	45	76	86	50
Percentage of living rhizome tips in an active condition	19	20	41	53

Table 5

Rhizome Development at the End of Three Years' Cutting Treatment and One Year of Recovery

Mean Figures from Three Experimental Areas (Sites A, B and F, p. 7)	Control	Cut I	Cut II	Cut III
Number of fronds per 100 sq. ft. showing in September	296	110	67	56
Frond height (in.)	66	48	32	32
Ratio: number of frond buds/ expanded fronds	2.45	2.23	5.86	5.63
Percentage of rhizome tips bearing a frond bud	45	48	68	75
Percentage of dead rhizome tips ...	23	53	92	87
Percentage of living rhizome tips in an active condition	18	16	74	66

Discussion. From the findings recorded above, it would seem that the main effect of severe cutting is a check on the growth of the plant, due to the death of a high proportion of rhizome apices. Continued severe treatment would leave only isolated living apices, and the denseness of the bracken association would consequently be reduced. An open association with few fronds—and those of low stature—is of little trouble to the agriculturist; it is the plant's powers of persistence and recovery which limit the usefulness of cutting treatment.

The causes of high mortality among rhizome tips in the treated plots are suggested by analyses taken at the end of two years' cutting (Table 4). In the repeatedly cut areas (Cuts II and III) an increase was seen in the activity of the rhizome tips, which would probably be more vulnerable than dormant tips to such external conditions as frost in exposed places or severe winters (Watt [10] and Conway [11]). On cut areas, little bracken litter will be left over the winter, and as a result the rhizome tips will be subjected to increased exposure.

Other workers (Smith [4] and Braid [5]) have commented on the smaller size of the frond after a period of cutting. Smith stated that smaller buds were found on the rhizome in areas subjected to a period of cutting, though he gave no measurements. Although he found no increase in the death rate among the rhizome apices, Smith described an increased rate of disintegration among the older parts of the rhizomes, a condition which he regarded as a result of the depletion of reserves from the stem by the increased number of fronds which developed with continued cutting. In our present experiment, it was the rhizome tips which were found to be dead and beginning to rot, while the older parts of the rhizome and all the apices still alive had considerable food reserves. It may be that food reserves do not easily move about through the plant; that the rhizome apex mobilizes the reserves of its own branch only; and that the reserves in branches continuously defoliated, producing fronds that are almost immediately removed, soon become depleted, with the result that the branch is capable of producing only smaller fronds.

Analyses from all our experimental plots confirm Watt's observations [10 and 12] that rhizome branches may show periods of dormancy during one or more seasons when no fronds are initiated, and that, at any one time, about half the branches from undisturbed rhizomes are without a differentiated frond bud (Tables 1-5). If our surmise is correct that the food reserves in a branch remain immobile inside that branch, branches which developed no expanding fronds during the period of cutting would still retain their reserves and so be capable of normal vigorous growth when their dormancy was broken. Thus it is probably branches such as these which contribute largely to the recovery observed when the cutting treatment ceases after three years.

A further source of re-establishment lies in the numerous abaxial buds which occur at the bases of the fronds. These buds seem capable

of lying dormant for varying periods and of then developing into secondary branches. Smith [4] believed such buds to be capable of long periods of dormancy, and cited examples of buds 18 years old. It is possible that buds of that age, even if living, may not be capable of developing—a point which can only be verified by experiment. At present we have no data on the length of time for which they remain capable of growth, nor on the extent to which they normally develop into secondary branches. The present series of experiments gave no indication that cutting stimulates their development, but other experiments have shown that in transplanted fragments of rhizome a proportion of the abaxial buds lose their dormant state and begin to develop as side shoots within a relatively short time.

Chemical Treatment

Chemical treatment has so far been less successful than mechanical treatment in the control of bracken. Contact weed-killers, such as sulphuric acid or sodium chlorate sprays, are effective only in such high concentrations that their use over a large acreage is uneconomic (Braid [13]). After an extensive series of tests on the effects of sodium chlorate as a herbicide for bracken, Braid [14] reported to the Agricultural Research Council that his general conclusions were that chlorate in sufficient strength to reach the roots (2-3 tons to the acre) would effectively kill the bracken in a localized area. But sodium chlorate is a contact weed-killer, and there was no evidence to suggest any translocation of the poison through the plant. Even Bates's method [15] of smearing the cut stumps of bracken fronds was, when tested in the west of Scotland, only successful when leakage caused the solution to run down the outside of the frond bases. Even then, deep-seated rhizomes were apt to escape. Soil sterilization by such drastic treatment would be quite impractical from an agricultural point of view, on account of the very heavy cost entailed in bringing back the land so treated into practical usage.

In 1953, through the courtesy of the Agricultural Research Council's Unit of Experimental Agronomy, another total herbicide, CMU (3-p-chlorophenyl-1,1-dimethylurea), was tested in the west of Scotland. The chemical was applied as a water spray at the rate of 100 gallons per acre, and plots were treated in mid-July with 20, 40, 60 and 80 lb. per acre. Early death or browning of the fronds and a good deal of scorching of the ground herbage resulted on all the plots, and by mid-September the numbers of dead fronds on the plots treated with 40, 60 and 80 lb. per acre were significantly higher than on the control plots, the percentage of dead fronds varying from 87 to 96 on the most heavily treated plots. But, as with sodium chlorate, only the fronds were affected, the rhizomes appearing to be quite unaffected when examined some eight weeks after spraying. The fronds were found to be dead and dried out as far as their junction with the rhizome, but the frond buds and the rhizome apices adjacent to the killed fronds were invariably unaffected. However, since a long-term effect is

claimed for CMU, final judgment must be delayed for one or two more seasons.

Growth-regulating Herbicides. Field tests with the growth-regulating type of herbicides have also been unsatisfactory (Egler [16] and Holly *et al.* [6]). In the west of Scotland, tests were carried out in the field with MCPA, 2,4-D and 2,4,5-T, and with mixtures of MCPA and 2,4-D, and of 2,4-D and 2,4,5-T. Pure chemicals and proprietary formulations were used, both at the recommended rates and at twice those concentrations. The fronds were sprayed at the crozier stage (late May), at the stage of full expansion (late June), and late in the season (end of August), when translocation of carbohydrate into the rhizome takes place (Hendrick [17]) and conditions for the transport of growth-regulating substances are probably most favourable (Weintraub [18]). In all cases, the effects of spraying appeared only on the fronds, the underground organs of the plant (apart from an occasional frond bud near the soil surface) remaining unaffected. The treated fronds showed contortions of the rachis and some reduction in the area of the pinnules which expanded after treatment. Small, dark necrotic areas also appeared on the parts of the frond where droplets of spray had fallen. No effect was shown on the rhizome, and fronds developing later in the season or in the year following treatment were normal in appearance and did not differ in number or height from those on untreated areas.

Further tests of the plant's reactions to growth-regulating compounds were carried out on young plants in pots : (1) to ascertain the possible uptake of growth-regulating compounds through the root system; and (2) to find the effects of growth-regulating compounds on the fronds.

In the first test young sporeling plants in pots were treated with the sodium salt of MCPA. A range of concentrations from 62.5 to 2,000 parts per million were used in water sprays, which were applied to the soil surface of the pots at 4-weekly intervals between May and August. Most of the solution must have come into contact with the plant system via the soil, but as the plants grew bigger some spray may have fallen on a few of the fronds. At the end of the growing season (mid-September) plants treated with the chemical in low concentrations (below 250 p.p.m.) showed increased growth, which was seen in increased frond height, a greater number of rhizome branches and markedly greater activity of the rhizome tips. In the plants treated with MCPA in strengths of 250 p.p.m. or more, systemic effects (that is, effects appearing at the growing points throughout the plant) were seen as contortions of the rhizome tips, curvature of the frond buds, and tumescences of the rhizome, which were frequently found with clusters of small roots near the rhizome apices. At concentrations of 1,000 p.p.m. and over, many of the rhizome tips were killed. But, at all strengths, the effects were not always shown ; and it appeared

that entry of the growth-regulating compounds through the roots was patchy.

To test the effects of growth-regulating compounds on the fronds, the sodium salt of 2,4-D (in the concentration of 1,000 p.p.m.) was applied to four series of young plants as follows :

Series 1. Single droplets of solution were put on intact fronds just below the youngest pair of branches.

Series 2. Single droplets of solution were applied to the cut ends of fronds from which the tips and uppermost pairs of branches had been removed.

Series 3. The tips of intact fronds were dipped into containers with solution.

Series 4. Fronds from which their tips and uppermost branches had been removed were dipped into containers with solution.

All the dipping fronds were left in position for 48 hours and were then removed. Control plants were similarly treated with distilled water. All the plants were analysed six weeks later.

Systemic effects appeared only as a result of dipping. On the plants treated with droplets, effects were restricted to the treated fronds, whether they were intact or had had their tips removed. Those from which the tips had been removed showed contortions of the rachis below the point of application ; on intact fronds, the pinnules which developed above the point of application were much smaller than those of the control plants. All effects diminished as the distance from the point of application increased.

Of the plants with fronds dipped into solution, a proportion showed morphological modifications at the rhizome tips, which were twisted and carried clusters of small roots near to the apices ; that is, they showed morphological modifications of the same nature as plants whose roots had received doses of growth-regulating compounds.

These preliminary tests suggest that growth-regulating compounds can induce morphological modifications at the growing points in young plants of bracken if they gain access directly to the vascular tract, but that such access is not readily achieved. The localized effects of the droplet experiment are paralleled by spraying treatment in the field : contortions may be effected with hormone-type herbicides in suitable strength, but the effects are concerned only with the point of contact on localized regions of the frond. The organ which should be the centre of attack—the rhizome—is left unscathed by such treatment.

A Future Line of Attack

The results of the experimental work described in this paper suggest that there is a high degree of resistance to attack by the growing regions of the underground stem of *Pteridium aquilinum*, and that attack through the fronds is not sufficiently effective to ensure complete control of the plant. Though the experiments were on a limited scale, the results appear to call for similar work on an extended scale and covering a longer period. Our findings suggest that future lines of attack on the

bracken plant should be directed against the rhizome, the organ on which the plant depends both for continuity and invasion.

Summary

1. The dominating element in the control of bracken on unploughable land is the fact that the organ of indefinite growth, the stem, is always underground, and therefore protected. The most frequently used mode of control is by direct attack on the fronds, which are the only exposed organs. Such attack may be either mechanical or chemical.

2. In recent experiments in the west of Scotland, the first observed effect of cutting away the fronds was an increase in the number which expanded in the following season. Significant effects were seen only after three seasons of severe cutting, and then, in experimental plots cut two or three times each year, a statistically significant increase was found in the number of dead stem apices, indicating that there was a decided check on the rate of spread of the plant.

3. In its normal undisturbed condition, bracken has a reserve of frond buds. After cutting, expansion of frond buds into fronds took place at a rate greater than frond bud initials were formed. At the end of the second year of treatment, the number of frond buds was significantly reduced, which would account for the decreased number of expanded fronds in the following season.

4. After three years' cutting, those rhizome tips still alive were capable of further growth and development. When treatment ended, recovery was made possible by an activity, increased beyond that of the controls, among the rhizome tips still surviving. By the end of the first season of recovery, following three years of treatment, a significantly increased frond bud reserve had been built up.

5. A further source of potential re-establishment lies in the large number of dormant stem buds present at the abaxial bases of the fronds. The causes which lead to these buds breaking their dormant state and growing out as secondary shoots, and the extent to which they may do so, are as yet unknown.

6. Chemical methods have so far been less successful than mechanical methods in controlling bracken. Substances such as sodium chlorate, when sprayed on to bracken areas, kill only the current fronds and leave the underground stems unharmed.

7. Herbicides of the growth-regulator type cause systemic effects in young sporeling plants when the chemical enters the plant system. Droplet contact on the fronds, such as takes place in spraying, is insufficient to produce morphological effects beyond the treated fronds.

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BLOAT: THE WORK OF THE PROVINCIAL BLOAT STUDY GROUPS

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Bloat of cattle and sheep, a disorder which is generally associated with sudden changes in diet, as when stock are turned into lush, rapidly-growing pasture, is a problem of long standing. Often the affected animal dies unless immediate veterinary aid is forthcoming. Fortunately, it does not reach very great proportions nationally: recent investigations in England and Wales show that in an average season less than one-half of one per cent of the total number of animals are affected by bloat. Nevertheless, the losses sustained locally or on a particular farm in bad seasons can be extremely serious. It is also alleged that trouble from bloat has increased in recent years and that the modern grassland system based on intensively managed leys is partly to blame.

Bloating is due to the accumulation of gas in the rumen caused by failure of the belching mechanism by which the animal normally gets rid of excess digestive gases. The cause or causes of this inhibition of belching is still unknown, in spite of veterinary and animal physiology studies carried out both in this country and abroad. There appear to be two types of bloat: frothy, in which the fermentation gases are dispersed throughout the digest; and non-frothy, in which the gas exists as a separate phase. The rapid fermentation of readily soluble carbohydrate in fodder appears to set up conditions in the animal rumen which are likely to lead to a bloat attack.

The increased attention directed towards bloat in recent years led workers in the South-Eastern Province of the N.A.A.S., and, later, in the East Midland Province, to begin systematic observations on the incidence of bloat, and of the conditions under which it occurred. The first of these investigations was begun in the autumn of 1948. Subsequently, they were extended to all N.A.A.S. Provinces by the setting up of Bloat Study Groups at each Provincial headquarters. These groups are composed of specialist advisory officers for crops, grassland and animal husbandry, with nutrition chemists and veterinary officers and, occasionally, research workers.

In 1951-52 the Bloat Study Groups carried out a co-ordinated national survey of bloat incidence in relation to environmental and other factors. The survey was conducted on farms selected at random, by means of a questionnaire, drawn up on the basis of experience already gained in the South-Eastern and East Midland Provinces.

Observations from Farm Surveys

The results of the first season's work (1951-52) confirmed some of the commonly recognized conditions associated with bloat attacks, and indicated some further ones. It would appear from these surveys that the incidence of bloat varies from season to season and is bound up in some way with weather conditions. The correlation between bloat and weather is often so marked that it has been suggested that warnings of the likelihood of bloat attacks might be given to farmers, based on the use of meteorological records, as in the case of frost forecasts.

There appears also to be some correlation between bloat and the stage and rate of pasture growth. Bloat occurs both in spring and in autumn. More bloat appears to occur on leys than on permanent pasture ; more on pastures in which clover and legumes predominate than on normal pastures. It occurs less frequently when stock have access to some form of roughage before or whilst grazing. Dairy cattle seem to be more prone to bloat than beef types ; likewise, certain herds, breeds or strains of cattle seem more susceptible than others. In Wales, a parish-by-parish survey of a cross-section of farms indicated that more bloat occurred on low-lying than on high-lying farms.

The surveys, however, gave no clear evidence regarding the cause or causes of bloat. Further work by the groups in the 1952-53 season was therefore aimed at obtaining more detailed information by studying specific herds or farms selected because of their previous history of proneness to bloat. It was intended that observation of the animals and of environmental conditions should be made both before and during bloat attacks.

The work of the Bloat Study Groups, and the local and national publicity which has recently been given to the bloat problem, has undoubtedly helped to achieve a closer degree of co-operation from farmers and veterinary surgeons. In many instances it may have led farmers to exercise greater care in the 1952-53 season, by not subjecting their herds to too sudden a change of diet when turning them out to graze after the winter feeding period. In this connection, it is of interest to note that in New Zealand a system of rationing of spring pastures by means of electric fencing has been advocated, as the result of trials to discover ways of avoiding bloat. This increased awareness on the part of farmers may have contributed in some measure to a reduction in bloat cases. At all events, the 1952-53 season was characterized by comparatively few outbreaks and the plans for carrying out an intensive rather than an extensive survey suffered in most provinces through lack of cases. Many of the Study Groups had by this time come to the conclusion that fundamental investigations in animal physiology were more likely to lead to the discovery of the basic cause of bloat than the empirical approach they had used hitherto.

In the meantime, the Study Groups were kept informed of developments in bloat studies in Scotland, New Zealand, the U.S.A., and elsewhere.

Clinical Investigations

A fresh impetus was given to bloat studies at a conference arranged by the Agricultural Research Council in November 1953, at which members of the Bloat Study Groups discussed the disorder with veterinary and research workers. This resulted in the current (1954) scheme of clinical investigations, in which the Study Groups are collaborating with the three research centres, the A.R.C. Field Station at Compton, Berks, the Grassland Research Station, and the Ministry's Veterinary Laboratory, Weybridge.

Earlier research work has indicated a number of possible bloat-inducing, or symptomatic, factors. For example, at Jealott's Hill it has been shown that bloat can be induced in rabbits by extracts prepared from lucerne. Similarly, American workers at Beltsville have recently used saponin extracts from lucerne and clovers to induce bloat in cattle. Investigations at University College, Aberystwyth, have pointed to hydrocyanic acid, arising from the hydrolysis of certain glucosides in clover, as a possible contributory factor.

The occurrence of a cholinesterase inhibitor in certain white clovers has been reported by Heath and Park of Pest Control Ltd., Cambridge. If a cholinesterase inhibitor can be absorbed by animals eating large quantities of clover, it might have a profound effect on rumen function. An attempt to assess the cholinesterase levels of blood and rumen wall of cows affected with bloat is in progress at the Agricultural Research Council Field Station, Compton.

To assist the investigations at Compton, arrangements were made for veterinary surgeons, farmers and advisory officers to notify the Station by telephone as soon as bloating occurred, so that the farms could be visited for the blood sampling and clinical tests needed in connection with the scheme of investigation. The scheme covered farms in the counties of Berkshire, Buckinghamshire and Oxfordshire, and a sufficient number of cases to enable this work to be carried out were received this spring.

It is proposed to combine this scheme of inquiry with clinical tests (for example, rumen pressure tests) on animals before and after allowing them to graze on pastures of different types. There is some evidence, for example, that pasture rich in fescue is the least liable to induce bloat. Another line of inquiry which will be pursued by the Field Station in connection with the cholinesterase activity measurements is the examination of the effect on cattle of large volumes of juice expressed from pasture grasses on bloat-free and bloat-prone fields.

ABSTRACTS

ANIMAL BREEDING

A Numerical Description of Breed Structure. A. ROBERTSON. *J. agric. Sci.*, 1953, **43**, 334-6.

Investigations into breed structure by various authors have shown that in a number of breeds only a small proportion of all herds supply the bulls whose genes are transmitted to all strata in the breed hierarchy. These herds are termed by Dr. Robertson the " effective " herds in the breed. In his paper he provides a formula for estimating their number. Work preliminary to using the formula involves finding out which herds have supplied the sires, grandsires, great-grandsires, etc., of a sample of animals. Using such data from other investigations, the effective number of herds is derived for six breeds of cattle, one of pigs and one of goats. In all cases the number is less than thirty. In this situation, breeding operations will have a permanent effect in the breed as a whole only in so far as they affect the small dominant group of herds.

Population Dynamics of the Dexter Breed of Cattle. G. B. YOUNG. *J. agric. Sci.*, 1953, **43**, 369-74.

A general statistical study on the Dexter breed of cattle was undertaken by Dr. Young, primarily because the losses incurred by the lethal " bulldog " might have a bearing on breed structure. The history of the breed shows a period of expansion from fifteen herds in 1900 to sixty-nine herds in 1925, a period of contraction to twenty-four herds in 1940, followed again by expansion. Average herd size in the earlier part of this whole period was about ten females, and twelve in the later part. Herds with more than forty females constituted 6 per cent of all herds, and held about 20 per cent of all females in the breed throughout nearly fifty years, in contrast with some other breeds where both proportions increased markedly over the same period of time. The average duration of life of Dexter herds is low (8.6 years for herds extant in 1947) compared with other breeds. The geographical distribution has changed little during the past fifty years, the majority of herds being found in the south of England.

The theoretical expectation when breeding from Dexter-type females is that four calves will be needed to replace her with one Dexter-type daughter, but rather more if normal mortality is taken into account. It is shown that nearly all Dexter-type females born were reared to maturity even during a period of decline in numbers. This left no reserve for expansion, which is thought to have been made possible only by lengthening the productive life of cows, and perhaps by breeding from some Kerry-type females.

Selection is largely confined to the bull side ; about one of every six males born was registered, one in nine left registered female offspring, and one in fourteen had registered male offspring. It is shown that, as in other breeds, a small proportion of all sires have a big influence in the breed, but the total inbreeding coefficient in 1947 was calculated to be only 2.4 per cent, suggesting that deliberate inbreeding is avoided. In spite of the fact that only half the calves born in the Dexter breed are available for replacements, some selection and some expansion of numbers is possible. This is a much more extreme situation than could be produced by an ordinary fully recessive lethal gene.

G.W.

Environmental Factors Affecting Body Size and Conformation in Rambouillet Yearling Ewes. D. W. Cassard, P. W. Gregory, J. F. Wilson, W. C. Rollins and W. C. Weir. *J. Anim. Sci.*, 1953, **12,** 140-7.

By using regression equations and fitting mathematical constants to growth measurements from Rambouillet yearling ewes, the authors were able to estimate and make corrections for various environmental effects. The data were collected from 135 ewes in the flock of the University of California in the years 1936-48. The measurements, which were taken at approximately 475 days of age, included withers height, depth and width of chest, loin width, heart girth, round measurements (the horizontal distance from patella to patella around the hindquarters of the animal), and body weight.

Age proved to be an important source of variation in all measurements except withers height. Twins were smaller than singles in all measurements except heart girth and round, whilst twins from 2-year-old dams were lighter and had smaller heart girth and round than twins from older ewes. Of the twelve rams, only two were used for more than one year ; consequently, no distinction could be made between the effects of sires and years. This was most unfortunate, as their combined effect was responsible for 40-80 per cent of the total variance in the various measurements.

J.H.W.

Fleece Studies

It is difficult to generalize for whole breeds when only a small number of experimental animals are involved, but the results emphasizing breed differences in recent work by Burns on lambs of different breeds are of interest[1, 2 and 3]. The material used was skin and wool samples from tattooed areas on two Romney, four Blackface and four Suffolk lambs. It was found that the ratio of secondary to primary follicles varied between breeds and also changed significantly with age. This ratio is low in the Blackface, as only a few of the earliest secondary follicles are contributing to the fleece at birth, but new follicles may be added to the population for at least twelve weeks. The Suffolk lambs,

on the other hand, have a very high secondary to primary ratio at birth, but relatively few follicles are initiated post-natally, all being established by six weeks of age. Changes in follicle and fibre density are due to formation of new follicles, growth of fibres within the follicles, shedding of fibres, and skin expansion.

Girth measurements and weighings were made for the four Suffolk lambs. After sixty-three weeks the lamb which showed the maximum increase in body weight and the greatest total increase in surface area, also had the highest value for skin expansion of any one tattooed square, and the highest mean value for skin expansion for all three squares, indicating that the measurements of the squares are a good guide to the general growth of the animal. The largest and heaviest lamb at birth had maintained its lead up to sixty-three weeks of age.

Dealing with the phenomenon of seasonal shedding, Burns found that in the Suffolk lambs not less than 25 per cent of the follicles shed their fibres in the winter months. There is no break in the fleece, such as frequently occurs in the Blackface, which is due to the failure of many secondary follicles to produce fibres. A small number of follicles continue to produce normal fibres throughout the winter, showing that follicular activity is possible in bad seasons. Poor nutrition alone does not bring about the autumn result, though it may cause shedding at other times of the year, and it is suggested that decreasing length of daylight may be the primary cause.

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J.M.P.

ANIMAL NUTRITION

Restriction of Food Intake of Pigs

Recent work [1] on this subject was carried out to test the effect under Canadian conditions of the method of restricted feeding advocated by workers at Cambridge [2, 3 and 4]. Since rate of muscle formation in the pig increases from birth up to 16 weeks old and then declines, while fat continues to increase to bacon weight, full feeding at first to produce quick growth followed by a slower rate obtained by restriction of feeding, produced the best type of carcass with a decreased proportion of fat.

In the work now reported, pigs were full-fed a 16 per cent protein ration (consisting of barley plus a protein-mineral supplement) from weaning to 110 lb. Thereafter, the protein in the ration was reduced to 13 per cent, and half the pigs were restricted in food intake while the other half were fed to appetite as before.

When the experiment was carried out in winter, the consumption of food from 35 lb. to 110 lb. live weight averaged about 4½ lb. per day and the daily gain was about 1¼ lb. Thereafter, the full-fed pigs ate an average of 8.3 lb. and gained 1.72 lb. daily, while the restricted ones ate 6.3 lb. and gained 1.27 lb. The time taken to increase from 35 to 200 lb. was 102 and 119 days respectively, and hence, since weaning took place at 56 days, the total time from birth to slaughter was less than six months, even for the slower group. The efficiency of conversion (amount of food per 1 lb. liveweight gain) was the same for both groups, but a significantly greater number of the restricted animals was graded first class ; and not only was the percentage of lean meat greater, but the actual size of the muscle area in the rashers was increased.

Under summer conditions, the restricted pigs were given the same amount of food as in the winter trial, but the full-fed pigs ate 1 lb. less than the corresponding winter pigs. There was only about a week's difference in finishing times, and efficiencies of conversion and gradings were both similar.

The conclusion arrived at was that reduction in growth rate in the later stages was the most important factor affecting grading, and this could be achieved by restriction of food at any season or by the increased maintenance requirements of the pig in cold weather. It was suggested that a reduction in the digestibility of the finishing ration by the introduction of more fibre could be a practical method, and this point was tested in further work by the same authors [5].

The method this time was to feed a ration containing 15 per cent of a protein-mineral supplement to 110 lb. and then to reduce the supplement to 10 per cent, the remaining 90 per cent being varied to provide differing amounts of fibre. Some of the results are shown in the following table :

Trial No.	Basal Ration (Percentage of Total Ration)	Daily Intake (*lb.*)	Daily Gain (*lb.*)	Number of Days from 115 lb. to 200 lb.	Percentage of Grade A Carcasses
1	90% Wheat	6.7	1.60	56	50
	45% Wheat, 45% Alfalfa ...	7.4	1.13	79	97
	90% Oats	7.8	1.50	60	90
	Significant Diff. (P=0.05)	0.3	0.10	5	
2	90% Barley	6.5	1.58	57	78
	65% Barley, 25% Bran ...	6.2	1.55	57	93
	45% Barley, 45% Bran ...	6.2	1.29	68	93
	Significant Diff. (P=0.05)	0.6	0.18	8	
3	90% Barley	7.3	1.55	58	48
	73% Barley, 17% Wild Oats	7.5	1.64	54	47
	65% Barley, 25% Wild Oats	7.3	1.53	59	62
	Significant Diff. (P=0.05)	0.5	0.12	4	

HOW THE BRACKEN PLANT REACTS TO TREATMENT

(see pp. 1-15)

Photo: *Scottish Farmer*

A West of Scotland hill grazing in August 1942 at the start of the bracken cutting experiments.

Photo: *K. W. Braid*

The same area in August 1950, cutting having been carried out at least once a year through the intervening years.

PLATE I

Photos: *W. Anderson*

EFFECTS OF GROWTH-REGULATING COMPOUNDS ON YOUNG BRACKEN PLANTS.

Plants received four treatments between May and August of 125 p.p.m. of MCPA. The effects were seen as (*a*) overgrowth of the fronds with a lack of rigidity; and (*b*) marked activity of all apical tissues on the underground stem.

Plant received one treatment (in August) of 4,000 p.p.m. of MCPA. Little effect was seen on the foliage, but there was considerable contortion of the underground frond buds and stem apices.

The difference in food intakes can be explained largely by the fact that Trials 1 and 3 were conducted partly in the summer and partly in the winter, whereas Trial 2 was entirely in the summer. In Trial 1, the increase in carcass quality was very marked when oats replaced wheat, but about 90 lb. more food was required. In Trial 2, excessive bran lengthened the time unduly.

When 25 per cent of the barley was replaced by an equal amount of bran or wild oats, carcass quality was improved without rate of gain, feed intake and length of feeding being affected. In other cases where an improvement in carcass quality was achieved, it was accompanied by the expected decrease in rate of gain. The writers were unable to offer an explanation for this difference. Presumably other factors inherent in the ration combinations were affecting the deposition of body fat.

In methods of self-feeding of pigs, knowledge gained on the above lines would be useful. Economies in labour are bound to be offset to some extent by greater food consumption and the risk of down-grading of carcasses, but if the greater consumption is provided for by cheap roughages, the cost of the food could be kept within reason and carcass quality perhaps also safeguarded. A very interesting account of work of this kind, carried out in Sweden, has appeared [6]. The main findings are given in the following paragraphs.

Experiments using an automatic feeder were started in order to work out conditions for highest carcass quality rather than maximum growth rate. Pigs of about 40 lb. weight were fed one ration until they reached 66 lb., then they were divided into four groups and used to test three different mixtures in each group ; the first from 66 to 110 lb., the second from 110 to 154 lb., and the third from 154 to 198 lb. During each period the protein and other constituents, except fibre, were adjusted to optimum, while the fibre varied from 4.8 per cent in the first group to 9.3 per cent in the fourth. Variations in fibre were effected by replacing meal by ground wheat straw.

Based on seven replications it was concluded that the most satisfactory growth was reached by the group to which the following data related :

Stage in Liveweight	Percentage of Fibre in Ration	Liveweight Increase per Day	Meal per 1 lb. Increase in Weight
lb.		*lb.*	*lb.*
44–66	6.0	1.38	2.62
66–110	6.4	1.46	3.15
110–154	6.7	1.77	3.63
154–198	6.7	1.90	4.01
44–198	—	1.64	3.46
66–198	6.6	1.69	—

It was emphasized that feeding by automatic machines should not be attempted unless the meal mixtures are well balanced in their proportions

of protein, energy, minerals and vitamins, apart, of course, from the dilution by the relatively inert high fibre material. Gradings were all very good, with increase of fibre tending to reduce fatness. The price of the food is reduced accordingly as the cheap fibre source is increased, but the most economic fibre level is that associated with optimum growth, that is, 6.6 per cent of fibre under the given conditions of management.

Some important work in Northern Ireland dealing with the effects of fibre in pig rations has just come to hand [7]. Six trials were carried out in which the contents of fibre ranged from 3.5 per cent to 11.5 per cent. It was found that increase in fibre was accompanied by decrease in killing-out percentage ; thus a pig fed a high fibre ration would have a lighter carcass than one fed a low fibre ration, although the live weights of the animals were the same. Carcass weight (that is weight of body after removal of blood, organs of body cavity and contents of these organs) was found to be correlated to thickness of back-fat and the high fibre pigs having lighter carcasses had thinner fat. It is pointed out that a high fibre diet, tolerated by heavier pigs, may retard unduly the growth of lighter animals and this, under the self-feeding system, may add to the difficulties in management associated with uneven pens.

Utilization of Glycerol by Ruminants

Although acetonaemia or ketosis is recognized as a clinical condition, it is probable that it can arise from several different causes, and therefore it is not to be expected that the same treatment will be equally effective on all occasions. However, the use of glycerol has proved beneficial in some cases [8]. Glycerol has also proved effective in combating twin-lamb disease or pregnancy toxaemia in ewes [9]. This is a form of ketosis and it often occurs when ewes, previously in good condition, receive a check in nutrition during the last month of pregnancy. Administration of 4 ounces of glycerol diluted with an equal amount of water and given at blood heat (or with the addition of a suitable drug) to favour direct passage to the abomasum, cured 14 out of 16 cases. The aim in treatment is to raise the abnormally low level of blood glucose, because by so doing the amount of the dangerous ketone bodies arising from the breakdown of fat is diminished. If glucose itself is used, it has to be given by injection, because it is rapidly fermented in the rumen. The fermentations of glucose and glycerol in the rumen have been compared in some work reported from New Zealand [10.] When 6 ounces of glucose in 7 ounces of water was introduced into a sheep's rumen, 80 per cent of it was fermented within thirty minutes, whereas eight hours after giving similar amounts of glycerol and water, 50 per cent of the glycerol remained. Further, the glucose gave rise to three acids—propionic, acetic and butyric—only the first of which forms blood sugar ; the two latter, in fact, are forerunners of ketone bodies. Glycerol, on the other hand, gave only propionic acid.

On this evidence it would seem that glycerol has distinct possibilities in countering some types of ketosis, its value being that (*a*) it is fermented slowly to antiketogenic propionate, which means that a *steady* stream of

sugar-forming material is reaching the blood, and (*b*) part of the glycerol will pass unchanged to lower parts of the alimentary tract to be absorbed there, and it is itself antiketogenic after absorption.

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S.M.B.

SOILS

Cation Exchange in Soils through the Moisture Range, Saturation to the Wilting Percentage. D. A. Brown. *Proc. Soil Sci. Soc. Amer.*, 1953, **17,** 92-6.

Studies of available water required for optimum plant growth indicate that the problem is mainly concerned with the amount of water necessary for transpiration, turgidity and metabolic processes. Since plant growth is also affected by the availability of cations, Brown set out to prove that soil moisture through the range from saturation to wilting point may also affect the rate and proportion of Ca, Mg, Na and K exchanged from the soil to plant roots.

Synthetic cation-exchange membranes were immersed in various soils containing amounts of water large enough to saturate the soil down to amounts low enough to cause wilting. The cations absorbed on the membrane were subsequently estimated, and it was found that the

amounts of cation absorbed increased sharply with the soil moisture content. At water concentrations sufficient to cause wilting the uptake of cations from light soils is much less than that from heavy soils, but when water concentrations are sufficient to saturate the soils, the uptake of cations from light soils is even slightly more than from heavy soils.

Of great interest to agriculturists is the fact that, as the moisture content increases, so does the percentage of readily available Ca and Mg, whereas the percentage of exchangeable Na and K falls. This explains why badly-drained soils produce symptoms of K deficiency in crops, even though soil analysis may indicate that the level of available K is quite satisfactory.

The Status of Soil Manganese as influenced by Moisture, Organic Matter and *p*H. P. D. Christensen, S. J. Toth and F. E. Bear. *Proc. Soil Sci. Soc. Amer.*, 1950, **15**, 279-82.

The writers have studied the changes in soil manganese as influenced by *p*H, organic matter and moisture. All combinations of the following three treatments were carried out :

1. Three *p*H levels.
2. Two rates of organic matter (cane sugar).
3. Three rates of moisture.

The exchangeable manganese was estimated at intervals of 7, 14 and 28 days.

Liming to reduce the acidity resulted in a large reduction in available manganese. The addition of organic matter to unlimed and limed soil released relatively large amounts of manganese, which, in the former, remained in the available state, but in the latter was rendered unavailable as soon as decomposition was complete. Moisture has both a direct and an indirect effect on the availability of the manganese. These two effects are not easily separated, but generally an increase in moisture content caused a drop in the available manganese.

The results clearly indicate the importance of soil organic matter and *p*H as far as the manganese status of the soil is concerned. On acid soils the ploughing-in of crop residues and their subsequent decomposition may release toxic quantities of manganese which remain available to crops for a long time. On the other hand, in neutral or nearly neutral soils the effect of organic matter would be short-lived, because of the rapid decomposition and immediate fixation of the manganese in an unavailable form.

Of the factors studied, the *p*H has the greatest effect on manganese availability, followed by organic matter and soil moisture content.

J. O. J.
W. M. D.

MACHINERY

Hydraulics in Agriculture. S. J. Wright and J. E. Bywater. *Conference on Hydraulic Mechanisms*, I.Mech.E., London, 1954 (in the press).

This paper deals mostly with hydraulic arrangements for controlling the operation of implements mounted on to tractors by three-point linkage. The writers estimate that about 85 per cent of the 32,000 wheeled tractors sold in the United Kingdom during 1952 were equipped with hydraulic lifts of this kind and are regularly used with mounted implements of one sort or another.

The fluid pressures used in the hydraulic systems of present models of tractors range from 500 to 2,200 lb. per sq. inch, and if farmers are to be able to use the tractor's built-in hydraulic system to operate the mechanism of tipping trailers and other equipment, then standardization of pressures will soon be essential. A high pressure of about 2,000 lb. per sq. inch is favoured by the writers on the grounds of saving weight and cost of valve gear and cylinders.

In most current tractors with built-in hydraulic systems the drive for the pump is taken from some point in the tractor transmission behind the main clutch, and the pump does not work when the clutch is disengaged. There is a growing demand for the drive to be in such a position that the pump is in operation continuously so that, for example, the raising of a hydraulically-operated loader can continue without interruption while the tractor is being manoeuvred from the loading point to the dumping area.

In discussing possible future applications of hydraulics to tractors, the paper mentions the power transmission unit being developed at the National Institute of Agricultural Engineering. In this transmission the engine drives a variable-delivery hydraulic pump which supplies radial piston-type motors built into the rear wheels of the tractor. This is a different approach from that normally adopted in automotive projects, where it is necessary for the unsprung weight to be kept to a minimum, yet it is a promising one for agricultural tractors. It may result in a tractor which, although as stable and adaptable as all present ones, possesses the agricultural advantage of having nothing but a skeleton framework to the rear of the engine fly-wheel.

Transmission of power to remote implements by means of a small hydraulic motor is also mentioned, but the writers say that experiments in this direction have not so far been wholly successful because of the problem of heat dissipation with relatively small volumes of oil. The cost of such a means of transmitting power to implements would need to be comparable with that of existing mechanical power-take-off drives.

H.J.H.
C.C.

The Steam Sterilising of Soil. The Application of Research to Practice. L. G. Morris. *National Institute of Agricultural Engineering Report* No. 24, 1954.

The fundamental principles of heating soil by steam injection and an indication of how the results of research work can be applied to commercial soil sterilization, giving improved fuel economy, are presented in this report. It points out that soil is able to condense steam up to a given rate, but once that value is exceeded, there is a rapid increase in the amount of steam wasted. The use of high steam rates is the biggest fault in practice and can be avoided by sterilizing a larger area at one time.

The size of plot which can be sterilized is determined by the boiler output : with a 1,000 lb./hr. boiler the area steamed should be at least 60 square feet. The best area for other boiler capacities can be arrived at by direct proportion. A good guide to efficient sterilization is that it should take about $1\frac{1}{2}$ minutes per inch of soil depth for the surface soil to reach 212° F. Normally, steaming will continue for a longer period than this to ensure that all the surface reaches boiling point.

The fuel requirement to steam different types of soil at various moisture contents is discussed. Before steaming, the soil should be as dry as possible : a heavy soil in a wet condition requires twice as much fuel as the same soil when dry, and light soils require 50 per cent more fuel when wet than when dry. Covering the soil surface with a canvas sheet spreads the steam evenly, ensuring no cold spots. Canvas is, however, a poor insulator and allows the surface to cool quickly after the steam is turned off. A one-inch layer of granulated peat provides good insulation but does not spread the steam as well as canvas. Hence, if peat is used the surface temperature should be checked at many points to ensure that there are no cold spots. It will keep the surface hot long enough for the heat to penetrate the centres of small lumps.

The requirements of injection equipment are stated, and a simple equation is given relating the output of steam to the pressure and the area of the holes in the equipment.

The various types of equipment and methods of steam injection are described. Where deep sterilization is required, Hoddesdon pipes give the best results. Longer pipes, similar to the Hoddesdon pipe, are recommended for use where the steam injection rate is at present too high. Pipes up to 15 feet long have been tested at the N.I.A.E. These long, single pipes give perfectly satisfactory results and one man can remove them from the soil without difficulty after steaming.

Sterilizing to a depth of 14 inches or less can be performed with a big reduction in labour by the use of the spike harrow method. All hand digging is eliminated, the soil being worked beforehand with a rotary cultivator. During sterilization the vertical spikes are simply pushed into the loosened soil.

The various types of boiler suitable for use with sterilizing outfits are dealt with in the report, and details are given of the modifications

required to convert an existing hot-water boiler into one which will produce low pressure steam, thus enabling one boiler to do both tasks.

The pressure drop in steam mains and the heat losses from the mains are described with the aid of graphs, and, finally, the writers have added some examples of sterilizing layouts to illustrate some common faults and show how they may be rectified.

G.P.S.
C.C.

FRUIT

Peach Growing

Le Pêcher. A. Desgraz *and others. Rev. rom. Agric.*, 1954, **10**, 1-8.

Although a number of the problems dealt with in this series of papers on peach growing in Southern Switzerland are purely local, some are of wider interest.

The peach probably succeeds best in a climate with hot, sunny summers and cold winters, but varieties vary so much in their adaptation to climate that it is possible to choose varieties to suit a wide range of conditions. A deep, easily-penetrated soil of a sandy, rather than a clayey, nature is preferred, especially one that has an underground supply of water.

Varieties. Only four varieties, all white-fleshed, are recommended, and they ripen between July 15 and August 20. It is pointed out that a greater number of varieties might result in too little of each reaching the markets to interest salesmen and that later varieties would clash with imported Elberta and J. H. Hale. Yellow-fleshed varieties, though poorer in quality, stand handling better, but none of them ripens early enough to suit the climate.

Rootstocks. On the light soil most favoured for peaches, the best rootstocks are peach seedlings from self-pollinated trees to ensure the greatest uniformity. Plum rootstocks are used where the soil is relatively compact or where peach seedlings have given poor results, and St. Julien A or Brompton are recommended. Seedlings of Brompton, if selected in the nursery before grafting, have been found satisfactory and uniform and are used instead of layers, owing to the difficulty of propagating the layers.* Ackermann, also difficult to propagate cheaply, appears useful but Myrobalan B is quite unsuitable. Almonds may prove valuable as rootstocks in very calcareous dry soils.

Pruning. Both the " classical " and the " free " method are described, since a choice between them cannot yet be made.

In the classical method a vase-shaped tree is formed by leader pruning

*In this country we would question the " uniformity " of the seedling stocks.

to an outward bud the 3-5 best-placed shoots that arise from the cut-back maiden. After the second year, the strongest horizontal laterals are retained for fruiting and the others are cut right out, except for a few well-placed ones, which are retained to extend the branch framework. At the end of three years, the spreading out of the vase is ended by cutting the leaders to inward-facing buds.

The free method may consist of some leader pruning for 4-5 years to encourage laterals, or of leaving the leaders uncut and retaining the terminal bud wherever possible. The other operations may involve the periodical thinning out of crowded shoots and branches, or simply the removal of entire branches as necessary.

The accepted practice in the area favours spring pruning just before blossoming, but summer pruning at the end of June has advantages, as it is then possible to direct growth into the shoots that are to produce fruit in the following year.

Pest and Disease Control. Among the various troubles dealt with, it is interesting to note that for Peach Leaf Curl a copper spray is recommended in the autumn after leaf-fall, as well as the usual spring application before flowering.

Effect of Soil Management Practices upon Growth and Fruitfulness of Peach Trees. *Univ. of Delaware Bull. No.* 300 (*Technical*).

In Delaware, the soils where peaches are grown are light, low in fertility and organic matter, and in many seasons there are periods of two or more weeks without rain. Soil management is, therefore, especially important.

An experimental orchard was planted in 1942 near Georgetown, in Southern Delaware, on a site containing four sandy-loam soil types. Twelve treatments, each replicated four times, compared clean cultivation; winter cover of rye-vetch; and winter cover of rye-vetch, ryegrass, and crimson clover, each with a summer cover of soybeans. Different levels of fertilizer were included as a pre-sowing treatment for the cover crops and, in addition, poultry manure was compared with nitrate (sodium or ammonium) applied round individual trees. A straw mulch treatment was added in 1949. The appropriate cover crops were sown in June or September after discing the plantation during late May and late August. No other cultivations were given but the tree rows were mown at least once during the summer.

The trial ended in 1951. The results showed that growth was severely checked for the first two or three years after sowing the cover crops, but later the trees under rye-vetch plus summer soybeans were larger than the controls and most of the other treatments. Winter rye-vetch alone, however, gave almost as good results, and from the practical point of view the inclusion of the summer soybeans appeared unprofitable. The effects of poultry manure were not significantly different from those of the nitrate fertilizers. Straw mulch was promising.

The data presented did not always agree with the suggestion that productivity is in direct correlation with tree size and vigour, but the best soil treatments did show superior production over clean cultivation.

Practices that Help Peaches. A. L. Havis *and others*. *Agric. Res. U.S.D.A.*, 1954, **2** (7), 8.

Soil management experiments at Beltsville were designed to study the interrelation of nitrogen fertilizer and cover crop treatments on Elberta, Halehaven, and Triogem varieties of peach. The orchards were planted in 1943 and, after three years, the treatments were begun ; the trees were grubbed after the 1952 harvest.

The skin colour of the highly coloured Triogem and Halehaven was not appreciably affected by nitrogen, but with Elberta the fruit from October-manured trees was of a higher colour than that from trees manured in March or those given an October-May-June split application, all treatments being at the rate of 3 lb. ammonium nitrate annually per tree. Discing-in the rye cover crop in early June instead of in mid-April or early May also improved the colour of Elberta. With all three varieties the highest yield was given by the split application.

H.B.S.M.

DAIRY BACTERIOLOGY

A Volumetric Platinum "Loop." N. J. Berridge. *J. appl. Bact.*, 1954, **17**, 15.

Having proved the "between workers" error of platinum loops, which can only be used for transferring small, often inadequate, volumes, the writer describes a platinum cylinder holding 9.43 $mm.^3$ (or about 0.01 ml.)—a very convenient volume for many purposes. This volume may be repeatedly dispensed with an error of less than ± 10 per cent. A single worker may show an error rarely exceeding ± 1 per cent.

Some Factors influencing the Survival of *Bacterium coli* on Freeze Drying. B. R. Record and R. Taylor. *J. gen. Microbiol.*, 1953, **9**, 475-84.

The finding of the writers, using *Bact. coli*, that the survival rate on freeze drying was a function of the numbers of organisms in the suspension which was dried, may be of importance to those who freeze-dry cultures of lactic acid bacteria, for example, to use as starters for cheesemaking.

The Methyl Red Test in Peptone Media. Mary G. Jennens. *J. gen. Microbiol.*, 1954, **10**, 121-6.

In glucose phosphate peptone broth the results of the methyl red test varied with the brand of peptone used. The same strains of *Bact. coli* grown in a defined inorganic salt medium plus glucose gave consistent results.

Factors influencing the Lactic-acid Producing Properties of Streptococci used in the Manufacture of Cheddar Cheese. I. Observations Relating Inhibitory and Stimulatory Phenomena. G. R. Jago. *J. Dairy Res.*, 1954, **21,** 111-21.

Single-strain starter streptococci failed to produce the expected acidity in cheese-milk pasteurized by the H.T.S.T. process during winter.

A few strains, however, were not so inhibited. In raw, unheated milk the susceptible cultures were even slower to produce acid, but when the same raw milk was boiled or autoclaved no inhibition was observed. The few cultures which were not inhibited in pasteurized milk grew equally well in heated or unheated milk. It was found that normal raw milk contains substances which inhibit " susceptible " organisms, and also other substances which stimulate all lactic streptococci. The inhibitory substance is present at all seasons of the year, is heat labile and is associated with the fat globules in the milk.

When separator slime was added to raw milk the cultures were stimulated, but this stimulation was not evident when small quantities of cream were added to the cultures. The growth-stimulating substances appear to contain a common growth factor which competes with the heat labile inhibitory substance, which may be enzymic in nature.

Starter Cultures and Bacteriophage. *The Dairy Research Institute (N.Z.) Annual Report*, 1952-53, 13-4.

An unusual case of phage infection in a cheese factory on the outskirts of a small town is described. The farmers supplying the factory with milk used the town water supply drawn from a river at a point upstream from the town. Above this point a cheese factory discharged its drainage into the river. It was found that the failure of the starter in the factory near to the town was due to bacteriophage in the water, derived from the factory upstream.

Growth Characteristics of Streptococcal Phages in Relation to Cheese Manufacture. V. L. Zehren and H. R. Whitehead. *J. Dairy Sci.*, 1954, **37,** 209-19.

There were differences in the susceptibility of various single strains of *S. cremoris* to bacteriophage infection during cheesemaking. Greater susceptibility appeared to be associated with more rapid growth of some phage races, causing a higher phage concentration in the whey and hence a higher degree of airborne phage infection. Those phage races which had a short latent period or a high burst rate reached a high concentration in the whey. The length of the latent period seemed to be the more important, but this and burst rate had a complementary effect.

Studies on a Psychrophilic Bacterium Causing Ropiness in Milk. C. Gainor and D. E. Wegemer. *Appl. Microbiol.*, 1954, **2,** 95-7.

A strain of *Alcaligenes viscosus* caused ropiness in milk at 5° C. but

not at 36° C. Capsules were evident at 5° C., indicating the psychrophilic nature of the organism. It differed from *A. viscosus* in that it did not hydrolyse fat, it fermented arabinose, glucose, galactose and xylose, and grew at 4.5° C. but not above 35° C.

A.T.R.M.

POULTRY HUSBANDRY

Nutrition

Among the many recently published papers dealing with the importance of B_{12} is one on the " Vitamin B_{12} Requirements of Hens as affected by Choline and Penicillin " by E. L. Johnson (*Poult. Sci.*, 1954, **33**, 100-7), which appears to be of great value to the practical poultry-keeper in assessing the economic importance of B_{12} supplements in his poultry diets. In the study described, chicks grew slowly on all vegetable diets when their parents had been fed a ration which resulted in the chicks having marginal reserves of the vitamin on hatching. Nevertheless, mortality was low among such chicks when fed a normal protein diet during the first month of their lives. Rapid early growth could be attained by B_{12} supplementation of the chicks' diet. Vitamin B_{12} appears to be of prime importance in the dam's diet, principally as a nutrient required to ensure good hatching. Supplements of choline or penicillin to the dam's diet did not alter the B_{12} requirements for hatching, nor were the growth or mortality rates of the progeny influenced by these additions to the hen's diet.

Discussing " Detergents and Chick Growth", H. D. Branion and D. C. Hill (*ibid.*, 62-6) refer to the widely differing results which have been reported when detergents have been employed in chick rations. Some authors have recorded substantial growth improvement; others have reported no improved growth rate and even a depression in growth. Branion and Hill found that in a series of rations the individual inclusion of six synthetic detergents and one soap at an 0.5 per cent level failed to lead to an improved growth response over the control chicks up to the end of a 12-week period. No response was observed in the same experiment following the addition of 10 parts per million of procaine penicillin to the experimental ration. This latter finding is interesting, and the writers discuss the implications arising from the failures reported elsewhere to secure growth improvements when supplementing the diets with antibiotics—particularly when the birds are housed in quarters not previously used for poultry. They suggest that the bacteria which can be inhibited by the antibiotic—or the detergent—may not always be present. They also suggest that the alternative theory that the " wetting " action of surfactants leads to more rapid absorption of nutrients from the intestinal tract is not borne out by their results.

One aspect of this general problem is discussed in a paper on " The Use of Procaine Penicillin in the Production of Table Poultry under Practical Conditions in the United Kingdom " by W. F. J. Cuthbertson

and H. Glasser (*J. Sci. Fd. Agric.*, 1954, **5**, 153-6). The writers found that a procaine penicillin supplement given from the first day after hatching to slaughter (at 15-17 weeks) with flocks at two different farms where poultry were normally kept, showed an improvement in total weight of 11 per cent and 15.4 per cent, respectively. This increase in weight of the treated flocks was partially due to improved growth and partially to more even growth and so a reduction in the number of culls. The penicillin supplement resulted in an improved food conversion rate up to 7 weeks of age, but this advantage had disappeared by the fifteen-week stage. In considering these results with those of Branion and Hill (*op. cit.*), it should be borne in mind that the birds were reared on established poultry farms, that is, chicks and older birds had been retained in the buildings and on the land for a prolonged period.

Much the same findings are reported in a paper on " Vitamin B_{12} and Penicillin Supplements in Poultry Nutrition " by R. F. Gordon, L. G. Chubb and C. G. Stacey (*Vet. Rec.*, 1954, **66**, 71). These workers also found that the influence of the antibiotic was not apparent with the mature birds and that a B_{12} supplement added to a ration low in animal protein did not maintain as good a growth as a ration carrying fishmeal as the principal source of protein. Birds in cages with an all-vegetable diet had a significantly lower egg production rate when compared with birds fed an animal protein ration. Additions of B_{12} to the vegetable ration led to no improvement in egg production. Gordon and his colleagues also found that birds on wire showed improved hatchability following additions of B_{12} to an all-vegetable ration, but a greater improvement took place if this was replaced by 5-10 per cent fishmeal. The hatchability of birds on the standard ration, that is, one containing 10 per cent white fishmeal, was improved by the addition of both penicillin and B_{12}.

Husbandry

In an interesting account of " Heritability of Chick Viability in a White Wyandotte Flock " (*J. agric. Sci.*, 1954, **44**. 221-6), R. W. Hale describes his experience of breeding over seven years for high and low brooder-house mortality between day old and eight weeks. With the separate establishment of a high and low mortality section, the low viability section consistently showed greater rearing losses. Viability over this stage appeared to have a relatively low additive heritability.

Discussing the " Length of Pre-incubation Storage and Heredity as Factors affecting the Hatchability of Turkey Eggs", I. L. Kosin (*Poult. Sci.*, 1954, **33**, 24-8) considered that the setting of eggs before they were seven days old led to no improvement in the hatching rate of fertile eggs. There was, however, a consistent decline in hatchability after seven days' storage. Kosin also found that genetic differences existed among eggs in the rate of aging of the blastodisc following pre-incubation storage (the greater the aging the lower the hatching rate). He emphasizes the importance to the hatcheryman of seeking (*a*) for those strains which

give better hatchability with eggs of equal age, and (*b*) those strains the eggs of which also retain a high hatching rate after a period of storage.

R.C.

ENTOMOLOGY

The Control of Mangold Fly *(Pegoinyia betrae*, Curtis) with DDT and other Chlorinated Hydrocarbons. F. G. W. Jones and R. A. Dunning. *Ann. appl. Biol.*, **41**, 132-54.

Laboratory and field trials have been carried out against this pest over a period of five years, using DDT, BHC and other chlorinated hydrocarbons ; parathion was also tested.

Good kills were obtained with high- and low-volume sprays, using DDT in the form of an oil emulsion ; dust and wettable powders containing DDT had to be used at excessive rates to obtain comparable results. BHC emulsions, toxaphene, aldrin and dieldrin gave similar results. Only parathion appeared to have any effect on the eggs, the remaining sprays only affecting the mining larvae, probably as the result of penetration of the leaf tissue by the insecticides.

Recommendations for control are given. Briefly they were that beet fields should be sited as far away as possible from the old fields ; a good, well-manured seedbed is important. Early sowing will ensure that plants have several rough leaves at the time of the attack. Late sowing after the middle of May avoids attacks by the first generation, but this would often lead to reduced yields. Gapping and singling should be delayed until all the eggs have been laid. Plants should be examined in the second and third weeks of May ; more than about thirty eggs per plant, when the plants are in the 6-8 leaf stage (fewer if plants are smaller), will indicate that spraying will be worthwhile.

The following sprays are recommended, but an assurance should be sought from the manufacturers that the preparations will not cause scorch :

1. 0.15 per cent DDT-oil emulsion at 50 gallons per acre.
2. 0.75-1.5 per cent DDT-oil emulsion at 10 gallons per acre.
3. 2-3 per cent DDT-oil emulsion at 5 gallons per acre.
4. 0.375 per cent aldrin, dieldrin or Y-BHC in oil emulsion at 10 gallons per acre.

Parathion should only be used by contractors having experienced spraying crews.

Nematode Resistance in Clover and Lucerne. Sven Bingefors. *Proceedings of the Sixth International Grassland Congress*, 1952, **2**, 1591-4.

The strains of stem eelworm (*Ditylenchus dipsaci*) attacking red clover and lucerne appear, in Sweden, to be quite distinct. Investigations are mentioned which show that nematodes from the same species of plant,

but from different places, may show differences. Two distinct races of stem eelworm occur on lucerne in the U.S.A., though no morphological differences were detectable. (Smith [1]).

In Sweden the investigations on red clover nematodes have not shown any such differentiation. The question of the occurrence of different biologic races is of great importance in breeding for resistance. Some of the earliest work was by Sylvén [2], who collected healthy plants grown repeatedly in the same infested field. Later this material produced the variety now known as Merkur, which was placed on the market in 1937. Later another strain, Resistenta, was bred in the same way by Akerberg. Such strains of clover have, however, not been found to be sufficiently winter-hardy for some districts in Sweden, and resistant winter-hardy strains are now being selected. These selections are also excellent starting material for crossing. In the laboratory, artificial infection of seedlings with eelworm is carried out, the seedlings being germinated in filter papers ; good correlation has been found between the field and laboratory results. A high proportion of resistant offspring has been attained from crossings.

The work is also concerned with resistance of lucerne to the strain of eelworm which attacks lucerne but not red clover. Investigation of this problem by Smith and Thorne in the U.S.A. is referred to. A lucerne strain, Turkestan 19304, was shown to have complete immunity against the eelworm. Later, a strain marketed under the name of Newmastan was found to be strongly resistant in Sweden.

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L.N.S.

VIROLOGY

Isolement d'une Souche de Virus Y de la Pomme de Terre (*Marmor upsilon* Holmes) a Partir du Dahlia et de la Tomate. C. Martin. *Ann. Inst. nat. Rech. agron. Paris, Ser. C. (Ann. Épiphyt.)*, 1952, **3**, 394.

At the Central Station of Plant Pathology, Versailles, in 1950, the writer transmitted to healthy tomato plants, from dahlias infected by tomato spotted wilt virus, a virus which produced symptoms usually attributed to Tomato Spotted Wilt. It was reisolated, and from inoculation and serological tests was identified as potato virus Y. On reinoculation to tomato, symptoms identical with those originally seen were produced. These results were confirmed in 1951, further inoculations demonstrating that it is possible for dahlias to harbour potato virus Y.

Yellow-net Virus Disease of Tomatoes. E. S. SYLVESTER. *Phytopathology*, 1954, **44**, 219-20.

A yellow-net virus disease of tomatoes has been found to occur sporadically in tomato plantings at Berkeley, California. The symptoms, expressed in all tomato varieties tested, are a pronounced yellow chlorosis of the veins and veinlets of infected leaflets. In initial phases of the disease the symptoms are bright colouration on new growth, but in both greenhouse and field crops the symptoms become less and less noticeable as infection ages. Normally, in a month or six weeks after onset, the vein chlorosis faded until it was no longer evident. The incubation period of the disease in the Marglobe variety ranged from 11 to 31 days. The only aphid species tested was *Myzus persicae*, which transmitted the virus with a low level of efficiency.

Because of the similarity of symptoms and vector to Yellow-net disease of sugar beet, reciprocal transmission tests with infective insects and both viruses and both hosts have been made. No cross transmissions were made so that it is likely that Tomato Yellow-net is a new virus disease.

The Yellow Dwarf Virus Disease of Cereal Crops. J. W. OSWALD and B. R. HOUSTON. *Phytopathology*, 1953, **43**, 128-36 and 309-13.

This paper gives an account of Yellow Dwarf disease of barley in California and its symptoms on barley, oats, wheat and rye. As its name implies, the main symptoms are stunting and yellowing of the plant, but in the case of rye there is little discoloration or stunting. In the other cereals the yield suffers considerably. The virus is aphid-borne and seems to have a wide host range among the wild grasses. Of 55 grasses tested experimentally, 36 species representing eight tribes of the Gramineae were susceptible, 20 displaying more or less pronounced stunting and yellow or red foliar discoloration. Sixteen species carried the virus without symptoms and the remaining 19 were immune.

Abstractor's Comment. It is of interest that on a visit to England this summer Dr. Oswald expressed the opinion that the yellow dwarf virus was present in this country. It is, however, different from the cocksfoot streak virus, which apparently does not infect cereals.

Diseases of Crucifers and Other Plants caused by Cabbage Black Ring-spot Virus. A. P. D. MCCLEAN and S. M. COWIN. *Sci. Bull. Dep. Agric. S.Afr.*, No. 332, 1952-53.

A comprehensive study was carried out in S. Africa on the diseases caused in cabbages, cauliflowers and other plants by the cabbage black ring-spot virus. Symptoms were mild in cabbage, cauliflower and endive, starting as small chlorotic spots, which changed to necrotic rings with a green centre. Stocks (*Matthiola incana*) were attacked moderately severely, suffering growth retardation with bushy development, and diffuse leaf mottle and crinkle. Iceland poppy (*Papaver nudicaule*), shirley poppy (*P. rhoeas*), and *Anchusa capensis* were attacked severely, showing diffuse leaf mottle, crinkle, chlorosis, and finally necrosis.

In opium poppy (*P. somniferum*) the disease produced rapid, lethal systemic necrosis.

The virus was readily transmitted by sap and by the aphids *Brevicoryne brassicae* and *Myzus persicae*.

Aphid Transmission of Potato Leaf Roll Virus. H. R. MacCarthy. *Phytopathology*, 1954, **44**, 167-74.

Non-infective, apterous individuals of *Myzus persicae* Sulz., allowed to feed for a minimum of five days on newly-emerged potato plants with Leaf Roll, transmitted the virus to about 70 per cent of *Physalis floridana* seedlings. Eighty-three per cent of apterous *M. persicae* proved capable of transmitting the disease. Alate *M. persicae*, fed for five days or longer on potato plants infected with the virus, were found to be capable of transmitting the virus for as long as they lived. A period on an immune host of up to twenty-four days, intervening between the acquisition and inoculation feedings, did not destroy the virus charge within the insect.

The latent period of the leaf roll virus in the aphid was found to vary widely with individual aphids, being between $9\frac{1}{2}$ and 120 hours.

Physalis floridana proved to be an excellent indicator plant.

Ring-spot-like Virosis of Rhubarb. J. W. Yale and E. K. Vaughan. *Phytopathology*, 1954, **44**, 118-22.

Virus-like symptoms, chlorotic spots and rings as well as necrotic stippling and rings, were observed in the leaves of rhubarb in the Willamette Valley of Oregon. The virus was transmitted to healthy rhubarb, Bountiful bean, broad bean, buckwheat, cucumber, curly dock, spinach, sweet william and zinnia by sap-inoculation. Symptoms produced on Bountiful bean and broad bean were comparable with those produced on these hosts by known strains of Tomato Ring-spot from cucumber. Inoculation tests showed that the virus occurs in naturally infected curly dock in the field.

Tobacco Necrosis Viruses affecting Tulips. B. Kassanis. *Plant Pathology*, 1953, **3**, 26-9.

Since 1949 sixteen outbreaks of tobacco necrosis virus in tulips have been observed in nurseries in the eastern and south-eastern counties of England. The origin of the bulbs could not always be traced, but in eight of the outbreaks the bulbs were newly imported from Holland. The variety Korneforos was affected in seven cases, and Alberio, Krelage's Triumph, Crater and Zimmerman, each in three. Transmission experiments showed that tulip varieties differ in susceptibility, and it is noteworthy that Korneforos, the variety most readily affected artificially, was also the one most often affected in natural outbreaks. The origin of these outbreaks still remains unestablished, but all the evidence suggests that badly-diseased plants pick up the viruses, not during the year in which they show the disease, but during the previous year, and that the viruses persist in the bulbs during the dormant stage. That bulb tissues

can act as symptomless carriers is shown by the fact that virus can always be recovered from the symptomless main and axillary buds of bulbs, the main shoot of which is necrotic.

Turnip Yellow Mosaic in Broccoli. H. E. Croxall, D. C. Gwynne and L. Broadbent. *Plant Pathology*, 1953, **2**, 122-3.

In an extensive survey of broccoli fields throughout the Northern Province in 1952, plants showing symptoms of Turnip Yellow Mosaic, which is transmitted by flea beetles, were observed on almost every holding inspected in the coastal area from Amble in Northumberland to the Tees. The disease was not found in the Berwick-on-Tweed area or on any holding farther west than twelve miles from the coast. On one farm, symptoms were also seen on Brussels sprouts, Ormskirk savoy and Alexander's late savoy.

The disease appeared to spread little during the winter but the symptoms tended to become more severe on affected plants, and many were stunted. The yellow areas on the outer leaves became necrotic and the leaves fell prematurely. Some of the affected plants were killed by frost, to which they appeared more susceptible than the healthy plants. During late March and April 1953, the disease spread rapidly. This followed an unusually mild, dry spell in early March, and flea beetles were seen early in April.

Virus Yellows of Shallots. D. M. Henderson. *Plant Pathology*, 1953, **2**, 130-3.

This disease, characterized by stunted growth and premature yellowing of the leaves, is widespread in Great Britain. The virus is sap-inoculable to shallots and onions and there are several aphid vectors. These are *Aphis fabae* Scop., *Myzus persicae* Sulz., and *Myzus ascalonicus* Doncaster. The two former species do not feed readily on shallots. Efficiency of transmission is greatly increased by a fasting period before infection feeding, and the virus seems to be of the non-persistent type.

The yield is greatly reduced by Shallot Virus Yellows, even in the first year of infection. Field observations suggest that progeny of infected plants are increasingly more severely infected from year to year. However, the rate of virus spread is slow and, with isolation, there seems no reason why a good stock should not be kept substantially free from infection for an indefinite period.

K.M.S.

COMMONWEALTH AGRICULTURAL BUREAUX PUBLICATIONS

Bureau of Horticulture and Plantation Crops

A new feature has been introduced into **Horticultural Abstracts,** the quarterly journal of this bureau.

Entitled *Salient Items*, it consists of a digest of the more striking phenomena described in the current number of the journal. This digest may be particularly useful to two classes of reader : firstly, those whose main interest lies in one particular crop or section of the abstracts, who would, however, like to know what is new in other horticultural fields but have not the time to browse through the abstracts ; and, secondly, the administrator and advisory officer who simply must have a general idea of what is afoot in every horticultural field, but similarly have no time for browsing. *Salient Items*, amended in accordance with suggestions received from readers, should considerably widen the journal's appeal.

There is a steady, ever-growing demand for two recent publications of this bureau, namely, *Sand and Water Culture Methods used in the Study of Plant Nutrition* (T.C.22) and *Field Experimentation with Fruit Trees and other Perennial Plants* (T.C.23). T.C.22 is not a treatise on soilless culture for the grower, as is erroneously assumed in some quarters : it is addressed to the investigator of nutritional problems. As such, in the words of the reviewer in the *Proceedings of the Soil Society of America* it . . . " represents one of the most comprehensive reviews to date of the methods involved . . . " and " summarizes in understandable form the best of the countless investigations in this field, and the technique evolved therefrom, since the time of van Helmont." Referring to T.C.23, a reviewer writes " This monograph . . . should be studied section by section by all engaged in experimental work on perennial crops, for it is full of wise advice."

It might also justly be pointed out that T.C. 23 is the first authoritative treatise on the layout of field experiments available to the investigator of perennial crops since Hoblyn's *Field Experiments in Horticulture*, which was issued in 1931.

Bureau of Pastures and Field Crops

Methods of Surveying and Measuring Vegetation. Dorothy Brown. Bulletin 42 of the Commonwealth Bureau of Pastures and Field Crops. July 1954, price 35s.

This is a review of the literature of the past thirty years on the methods and techniques used by workers in quantitative ecological studies of vegetation, particularly of the many types of grazing land. The review classifies the different methods which have been, or are being, used and describes and discusses the various techniques employed in botanical analysis and in studies of the productivity, as well as the utilization, of herbage. The grassland agronomist will find methods of surveying and

measuring vegetation suitable for all types of grassland and will be able to judge the comparative merits of procedures used by other investigators, both past and present.

Mr. G. M. Jolly of East Malling Research Station has contributed a chapter on the theory of sampling, with particular reference to the subject-matter of the book.

BUREAU OF SOIL SCIENCE

Reviews in recent numbers of *Soils and Fertilizers* likely to be of interest to advisory services include: "Biological Effects on Nutrient Availability" (Vol. XIV, No. 1); "A Survey of the Use of Chemical Tissue Tests for Determining the Mineral Status of Crop Plants" (XIV, 3); "Krilium" (XV, 2); "Some German and Austrian work on Soil Compaction and Fertility" (XV, 4); "Interactions of Soil and Antiseptics" (XV, 5); "The New Era of Aerial Farming" (XVI, 2).

The **Bibliography of Soil Science, Fertilizers and General Agronomy, 1950-1953,** contains 8,000 classified references to all papers of significance which have appeared during the period on every aspect of the sciences of the soil, fertilizers, and crop nutrition. It is indispensable as a reference book to the literature of soils, and costs 40s.

Copies of all bureaux publications can be obtained from the Central Sales Branch, Commonwealth Agricultural Bureaux, Farnham House, Farnham Royal, Bucks.

PROVINCIAL NOTE

ORGANIC MATTER IN SOME EASTERN COUNTIES SOILS*

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A number of well-known experiments to assess the value of organic matter to soils and crops have been carried out in eastern England. They have been on soils of different types under different systems of farming and have lasted for many years, yet the results have shown little benefit to crops and may usually be attributed to the nutrients in the organic matter used.

*This paper was given by Dr. Pizer at a recent conference at which the importance of soil organic matter in eastern counties farming was discussed by research workers, farmers and advisory officers. A report on the conference as a whole will be available in due course.

The experiment at Rothamsted was on a soil derived from clay with flints, a type which is of limited extent in the Eastern Province, being confined almost entirely to west Hertfordshire. The one at Woburn was on a deep, loamy sand derived from the Lower Greensand, with a water supply at 2-3 feet, a combination which occurs comparatively rarely. The ground water supply is usually lacking in sandy soils and depth is variable. The experiment at Tunstall was on a high-lying, loamy, coarse sand, containing over 60 per cent coarse sand and only 1 per cent organic matter. Water is probably the chief limiting factor on this soil. The experiment at Saxmundham was on a very heavy soil, representative of shallow, heavy soil with impeded drainage on chalky boulder clay, an extensive glacial deposit in the Eastern Province.

Experience of problems, as distinct from experiments, has shown that organic matter appears to be valuable in many soils in the Eastern Province in preventing deterioration of soil structure during the growth of crops and in improving the rate of supply of nitrogen. It may be that these problems did not arise on the experimental sites because of the nature of the soils.

Instability of soil structure is commonly due to high proportions of fine sand, very fine sand, or silt in the soil, along with low amounts of organic matter. These fine particles are not firmly held in many soils, and they tend to flow when wet, settling out into layers in the soil or forming hard crusts. Cultivations are necessary to break layers and crusts, or crops suffer. In 1951 serious troubles occurred in sugar beet in many parts of the Eastern Province, due to flowing of the silt and fine sand fractions when the soil was wet and to a structural collapse which left a badly aerated mass of soil to a depth of 10-12 inches. Soils having this property are widely distributed in the Eastern Province. They extend round the coast in a broad belt from the Wash to the Thames Estuary. They occur on the boulder clays of Huntingdon, Suffolk and Essex, on the fine glacial sands of Norfolk, on alluvial deposits in river valleys, and in the loams and brickearths of East Norfolk and Essex. Outside the Province, there is a vast area on the High and Low Wealds of Kent and Sussex and also over the brickearths of these counties.

Effects of organic matter on the nutrition of crops are mostly noticeable in relation to the nitrogen supply. When the organic matter becomes low or very low, symptoms of lack of nitrogen often show in crops unless more nitrogen than usual is applied. In cereals, yellow or pale green areas appeared in spring, in contrast to the uniform green of cereals on soils containing more organic matter. In fruit trees in Suffolk and Essex, nitrogen deficiency symptoms often appear, even with high nitrogenous manuring. On these soils, low or very low in organic matter, farmers and growers have learnt by experience the need for heavy dressings of nitrogen. This interesting fact was confirmed by the

fertilizer survey carried out in north-west Norfolk in the summer of 1952 by the advisory soil chemists of the N.A.A.S. in co-operation with Rothamsted.

What levels of organic matter may be regarded as low or very low in the soils of the Eastern Province ? Under systems of farming in which three-year leys are used and farmyard manure is returned to the land, the levels of organic matter found are 3-4 per cent on the light to medium textured soils, and 4-5 per cent on heavier land. Troubles due to low organic matter are not seen on such soils. Where, however, the system of farming is almost entirely arable, with no leys, or leys of one-year duration only, the straw is burnt and no farmyard manure is returned to the soil, the level of organic matter is usually below 3 per cent, often below 2 per cent, and sometimes below 1 per cent. Problems of the kind already mentioned occur on these soils, increasing in severity as the level of organic matter falls.

On the basis of this experience, levels of organic matter* are classified as follows :

1. Extremely low (less than 1 per cent). Found where serious problems occur. A dangerous condition requiring immediate action to restore organic matter.
2. Very low (1-2 per cent). Instability of soil structure found together with the bad effects of layering and panning in soils. Uneven response of crops to nitrogen and a higher demand for nitrogen.
3. Low (2-3 per cent). Physical problems in some seasons and in situations with impeded drainage.

Causes of Low Organic Matter

The chief cause of low levels of organic matter in these soils is oxidation of the organic matter during the autumn and spring, when the soils are moist and warm and well aerated by cultivations. Such losses are high in the black fens, and may amount to 40 tons per acre per year on the deep peats. Losses are also high in old pastures after ploughing, probably amounting to 5-10 tons per acre per year, but they are relatively low in old arable land, because the amount of organic matter in the soil is low and resistant to breakdown, and little is added from crop residues.

Other causes of low organic matter are erosion by blowing on the sandy soils and by run-off on slopes of both light and heavy soils. Erosion should not be over-emphasized, but evidence that it has occurred is to be found. Deep ploughing, too, must bear its share of responsibility. Organic matter from the roots of grasses, clovers and arable crops is added largely to the top six inches of soil, where it is of most benefit to crops in the seedling stage. Deep ploughing buries the organic matter added by the leys, etc., and brings soil low or very low in organic matter to the surface. Eventually, the organic matter, or

*Levels of organic matter as determined by wet oxidation, according to the technique described by J. Tinsley (*Trans. Int. Congr. Soil Sci., Amsterdam*, 1950, **1**, 161-4, and *in lit.*).

what is left of it, becomes thinly distributed throughout the depth of ploughing.

Some soils that are now very low in organic matter at one time contained 8-12 per cent of organic matter. Some of the silts around the Wash have fallen from a high to a very low level, and it is instructive to visualize the changes that have taken place. The mineral composition of these soils is high in very fine sand and silt, and textures ranging from very fine, sandy loam to silty clay loam are commonly found. When broken from pasture, they were high in organic matter and granular in condition. They worked easily, drained well and were perhaps difficult to make firm. As the organic matter disappeared under arable cultivation, the physical nature of the soils slowly changed. The granular condition and " puffiness " first disappeared, then the silt and very fine sand became less firmly held and began to " flow " when the soils were wetted, reducing air and drainage channels. Finally, a compact layer began to form at plough level, and the surface started to cap. Deeper ploughing was tried to deal with these conditions, to take water away from the surface during winter, and to leave a drier surface soil for cultivations in the spring. Soils in this condition are found to contain under 3 per cent organic matter ; some contain under 2 per cent and a few less than 1 per cent.

Difficulty of Restoration

The problem of restoring organic matter to these soils is a long and difficult one, especially if the only return is from the roots of arable crops. A rise of 0.1 per cent of organic matter requires approximately 1 ton per acre in a depth of six inches, and to supply this amount of fairly stable organic matter to the soil several tons of fresh plant material may be needed.

Under arable conditions in the Eastern Province I would estimate the annual returns of organic matter from crop residues to be as follows :

Roots. ½-1 ton per acre from cereals ; 1-2 tons from the roots of clovers and grasses ; very little from potatoes and sugar beet.

Tops. 1-1½ tons from the straw of cereals ; 1½-3 tons from the tops of sugar beet ; very little from potatoes.

Thus where the farming system is such that cereals, potatoes and sugar beet are grown without leys and cereal straw is burnt, the only returns of organic matter of any size are from the roots of cereals and the tops of sugar beet.

Now, let us suppose that the returns of organic matter are insufficient to check the fall of organic matter in the soil and a point is reached where the growth of crops begins to fall off due to the physical and nutritional causes I have mentioned previously. Patches of poorer growth, not so noticeable at first, will begin to appear in crops, the return of organic matter will become less and less as the crop deteriorates, and eventually

very definite poor areas will be seen. This condition has apparently been reached in some of the arable soils of the Eastern Province. Areas of poor growth are appearing and in them the organic matter level is of the order of 1-1.5 per cent, compared with levels that are 0.3-0.6 per cent higher in the better parts of the field. It is always possible to confuse cause and effect in making observations in the field, but these differences and low levels of organic matter are so often associated with poor areas in fields that low organic matter may well be the cause of the trouble. Experiments with organic matter are needed on these soils to determine whether this is so.

Response Depends on Existing Level and Soil Type

I suggest that the response of soils to organic matter will depend on the level of organic matter in the soil—as with responses to phosphate and potash—and to the physical properties of the soil. From observations in the field it appears that response to organic matter is not likely to be very great if the level of organic matter is above 3 per cent, and should be very marked when the level of organic matter is below 2 per cent, particularly if difficult physical conditions are associated with low organic matter.

No experiments seem to have been carried out on soils of this kind. Figures of 4-5 per cent organic matter have been mentioned for Saxmundham, Rothamsted and Jealott's Hill. In the Woburn soil the level of organic matter appears to be 3-4 per cent. This soil also has a moisture supply at 2-3 feet, so that once the critical seedling stages have been passed and the roots are spreading through the soil, only nutrients are needed. The Tunstall soil is the only one with very low organic matter; with 60 per cent coarse sand there are likely to be no physical problems except lack of moisture, and this may be the limiting factor.

We should endeavour to put down experiments where organic matter appears to be needed. On a problem soil in north-west Norfolk, the effects of organic matter, including straw, have been outstanding. The experiment was started in 1951 with sugar beet and continued in 1952 and 1953, using sugar beet in both years to measure residual effects. The results for 1951 and 1952 are given overleaf. In 1953, the sugar beet were badly damaged by what is known as the "Docking Disorder."

The level of organic matter in the soil was 1-1.3 per cent and the texture was loamy fine sand. In each year the whole experimental area received 3 cwt. sulphate of ammonia, 3 cwt. superphosphate and 2 cwt. muriate of potash when the seedbed was prepared, but the treatments listed in the table were applied only for the 1951 crop.

Approximately the same amount of organic matter was supplied by 3 tons of straw, 20 tons of sugar beet tops and 15 tons of farmyard manure. The effect of 3 tons of straw plus 3 cwt. of sulphate of ammonia was roughly equivalent to 10 tons of farmyard manure each year.

Treatments	Yield 1951			Yield 1952		
	Roots	Sugar	Sugar Response	Roots	Sugar	Sugar Response
	tons per acre	*cwt. per acre*	*cwt. per acre*	*tons per acre*	*cwt. per acre*	*cwt. per acre*
Control ...	12.1	39.5	—	8.8	28.3	—
10 tons farmyard manure	14.0	47.2	+7.7	11.1	35.7	+7.4
20 tons farmyard manure	15.0	50.4	+10.9	12.1	40.3	+12.0
3 tons straw plus 3 cwt. S/A*...	13.9	47.2	+7.7	11.3	35.5	+7.2
20 tons sugar beet tops ...	15.1	50.1	+10.6	10.8	34.1	+5.8

*The sulphate of ammonia was applied in February 1951.

The differences in yield in this experiment were achieved by uniformity and greater vigour of growth on the treated plots. On soils already having this property, much less benefit from organic matter is to be expected. But should farmers wait until soils are in a condition to respond before applying organic matter to them ? The answer from experience of the problems which may arise and the difficulties or restoring organic matter, is quite definitely " No ". Troubles due to low organic matter and unstable tilths are largely encountered on soils under purely arable rotations in which the return of organic matter to the soil is very little. Many years may elapse—as has happened on the silts around the Wash —before low or very low levels of organic matter are reached, but this condition appears to be inevitable. There does not appear to be need for a change in policy to building up organic matter to a high level or to restoring a granular structure to the soil—even if this were possible under arable farming. What seems to be needed is an increase in organic matter above a minimum level—which may be between 2.5 and 3.0 per cent— and this is achieved according to observations in the field when farmyard manure is added to the soil or the latter is rested for a short period under a ley crop.

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